# THERMAL DETECTOR TECHNOLOGY DEVELOPMENT IN THE OFFICE OF AEROSPACE TECHNOLOGY


International Workshop on Thermal Detectors

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Chris Moore

Code R / NASA Headquarters

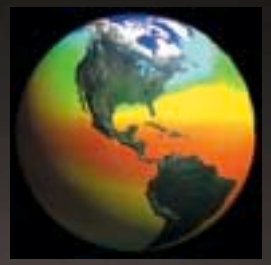
christopher.moore@nasa.gov

# The Aerospace Technology Enterprise Contributes to the NASA Vision and Mission through Technology Development and Transfer

## NASA Mission

OGA & Industry Partners

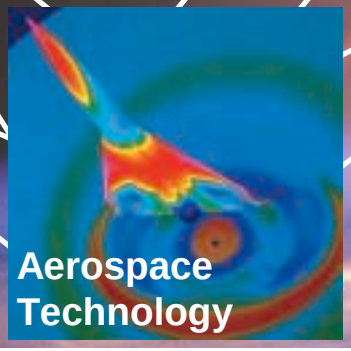
Space Science



Earth Science

Biological & Physical Research

Non Aerospace Industry & Educators



Aerospace Technology

Space Flight

# Mission & Science Measurement Technology

Theme Objectives and Programs

## Theme Objectives

**Mission Risk Analysis**

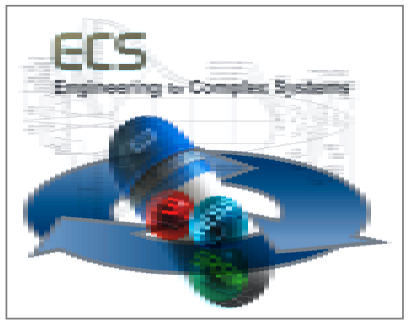
Develop the capability to assess and manage risk in the synthesis of complex systems.

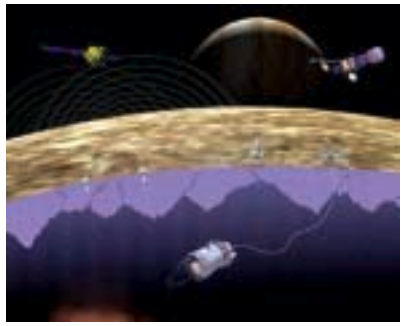
**Science Driven Mission Architectures and Technology**

Define new system concepts and demonstrate new technologies which enable new science measurements.

**Create Knowledge from Scientific Data**

Develop break-through information and communication systems to increase our understanding of scientific data and phenomena



## Programs

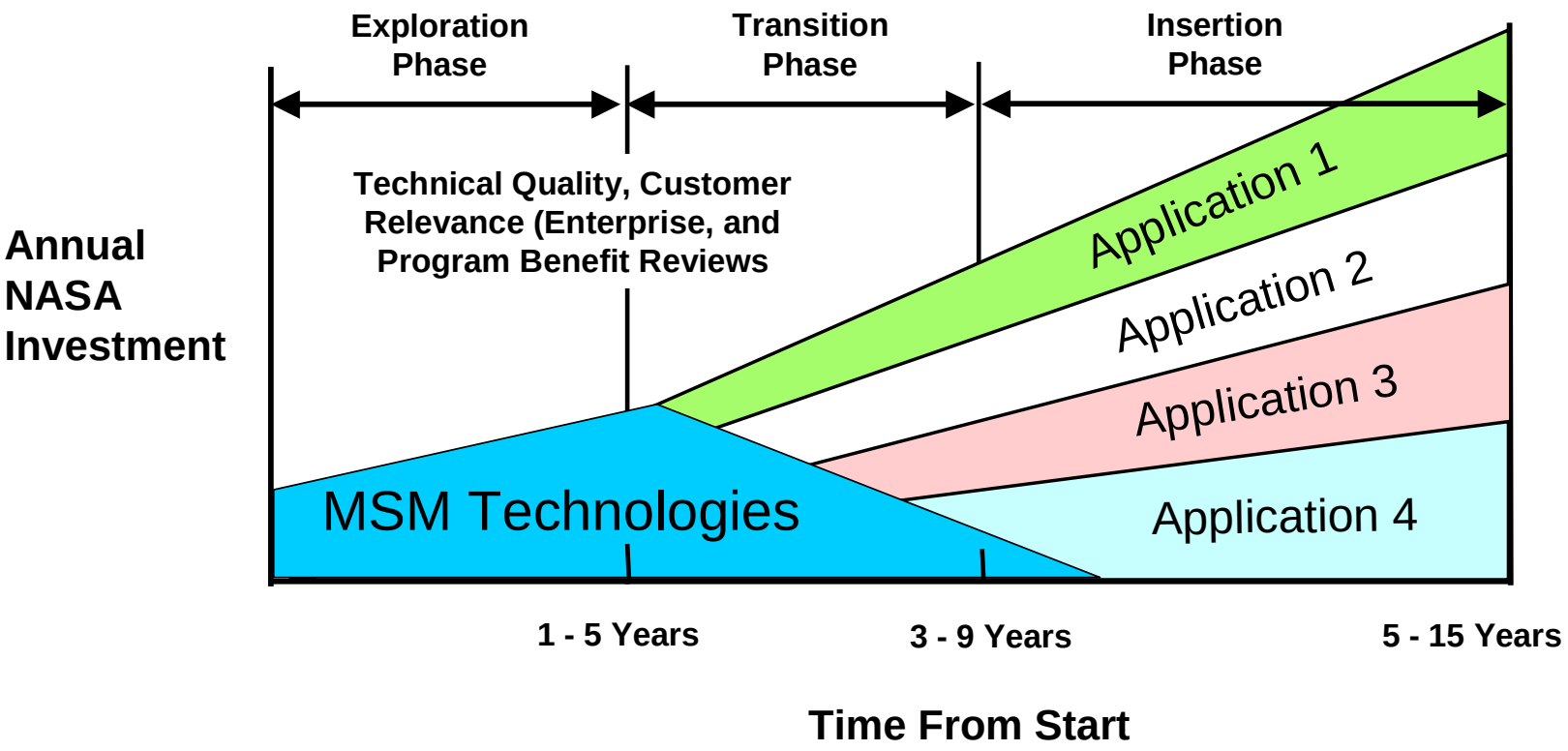
**Engineering for Complex Systems**

**Enabling Concepts & Technologies**

**Computing, Information & Communications Technology**

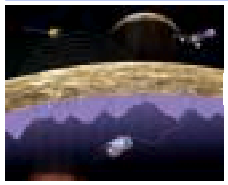
# Mission and Science Measurement Technology

## Development Strategy



# Enabling Concepts & Technologies Program

Projects

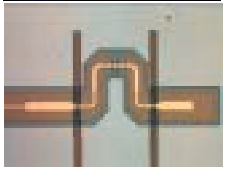


**Advanced System Concepts**

*Conceptual studies and systems analysis of revolutionary aerospace system concepts that have the potential to leap well past current plans, or to enable new visions for NASA's strategic plans.*

**Energetics**

*Development of advanced power and propulsion technologies to enable lower-cost missions with increased capability, and to extend mission reach.*



**Advanced Measurement and Detection**

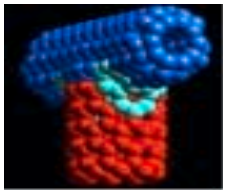
*Development of miniaturized, highly-integrated, and efficient instruments and sensors to provide increased scientific return.*

**Revolutionary Spacecraft Systems**

*Development of revolutionary spacecraft systems and architectures to enable distributed science data collection, explore extreme environments, and lower mission costs.*

**Large Space Systems**

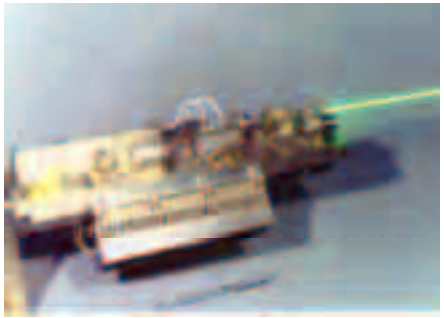
*Development of concepts for large, ultra-lightweight space structures and apertures to expand mission capabilities, and enable new visions of the Earth and the Universe.*



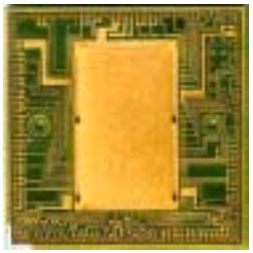
**Space NRAs**

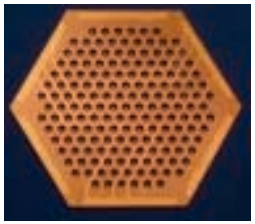
*Broadly announced peer-reviewed solicitations to capture innovative ideas from external organizations, to leverage high-payoff emerging technologies, and to complement NASA capabilities in critical areas.*

# Advanced Measurement & Detection Technologies



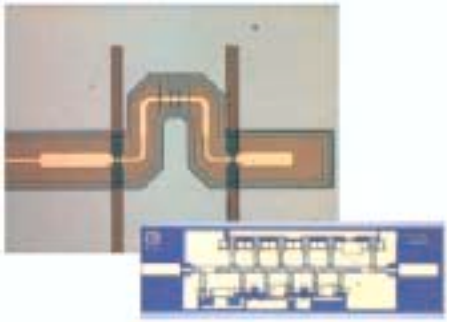
High efficiency, tunable laser transmitters for active sensing





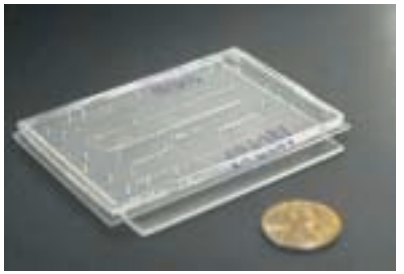
High efficiency detectors (IR, visible, UV, X-ray) for focal plane assemblies

Instrument optics



Submillimeter sources, amplifiers, and detectors


Cryocoolers

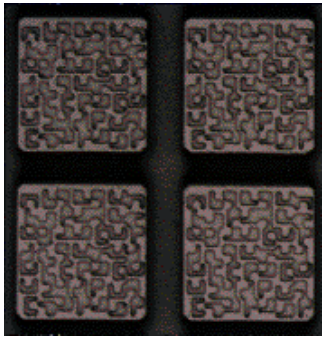


In situ biochemical sensors

# *Direct Detectors and Focal Planes*

## MW/LW Infrared

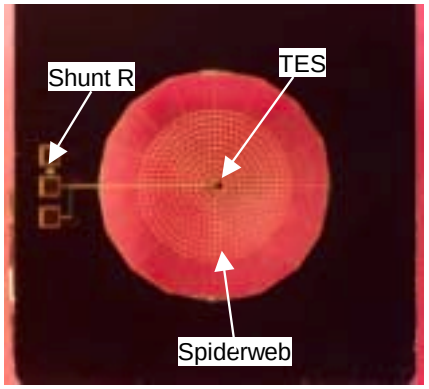
**Uncooled IR thermopiles**
**Quantum Well focal planes**

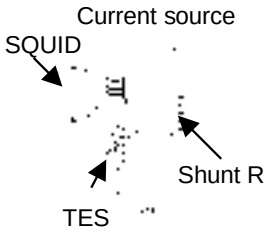


**Quantum Well Infrared Photodetector (QWIP) pixels**

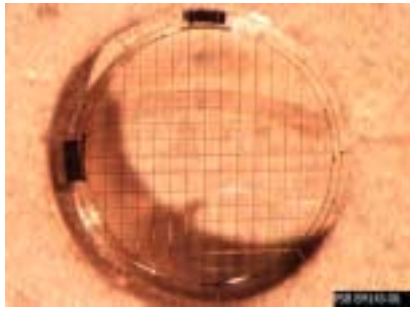
## Far Infrared

**Si:As BIB arrays**
**Micromesh Bolometer Arrays**
**Superconducting TES and Kinetic Inductance**



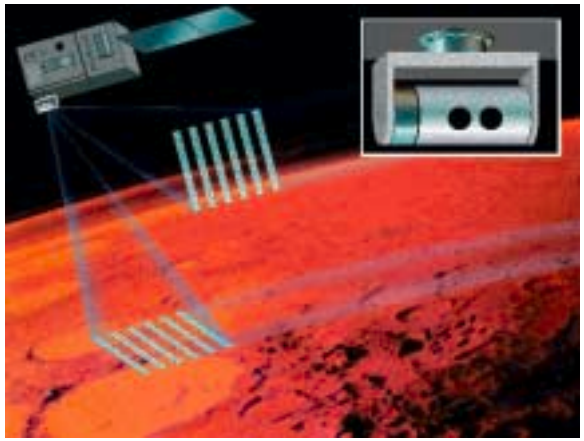




**Superconducting TES bolometer**

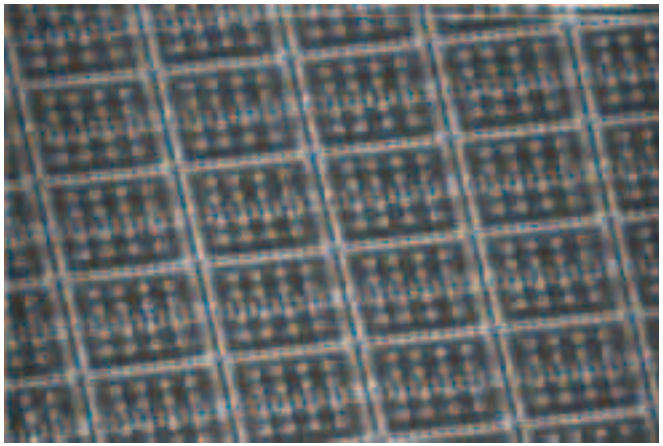


**Micromesh bolometer**

# *Uncooled Thermopile Broadband Detector Arrays*



**Mars Climate Sounder**

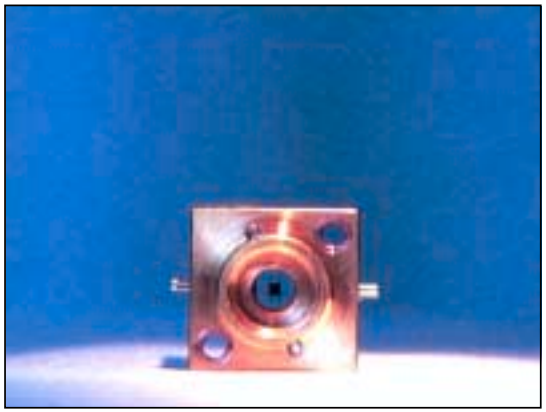


**Prototype Thermopile 2D Array**

- Accurate thermal radiometry without temperature stabilization or optical chopping
- Developing 128x128 arrays with $D^*=10^9$ $cmHz^{1/2}/W$ and 20 mW power.
- Thermopile linear detectors selected for 2005 Mars Reconnaissance Orbiter atmospheric sounder
- Smaller, lighter, lower power instrument (7 vs. 40 kg, 10 vs. 40 W)
- Investigator:  Marc Foote - JPL

# *Superconducting Bolometers*

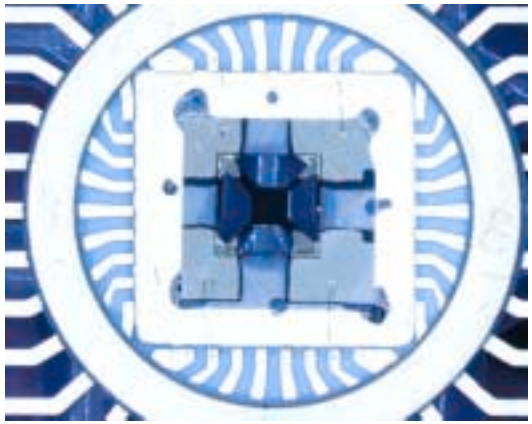
**TES Bolometer**



• Transition Edge Superconducting (TES) Far IR bolometer operating at 90 Kelvin

• High Temperature Superconducting GdBCO thin film on 7 µm thick single crystal sapphire

**HTS Bolometer**



• Single pixel and 2 D arrays of (HTS) bolometers:
  – Substrates: monolithic sapphire and/or SOI ( Ò1 µm thick)
  – Sensing elements: YBCO and MgB2 thin films
  – Operating temps: 40K ÒT Ò90K

• First fully functioning HTS bolometer on monolithic sapphire membrane - May 2003

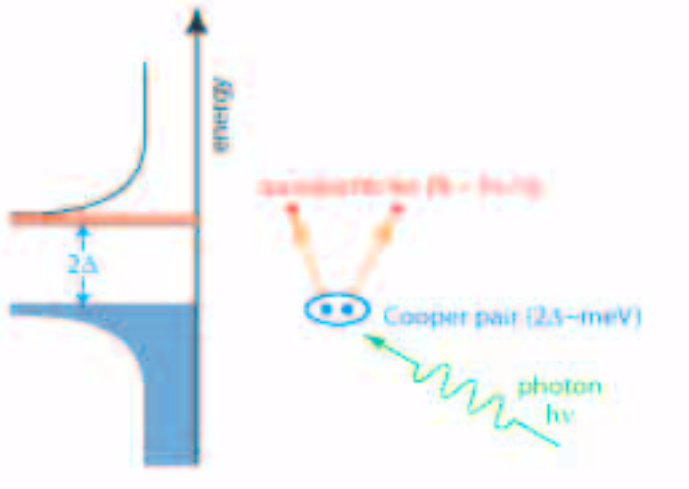
• Investigator:  Brooke Lakew - GSFC

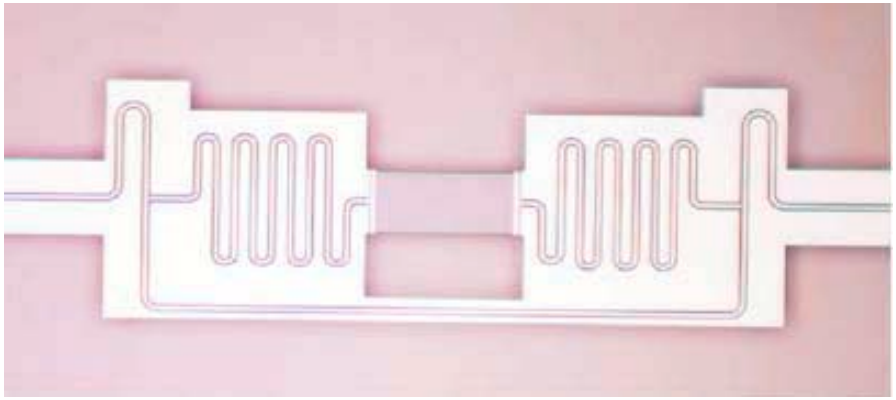
# *Kinetic Inductance Detectors*

- Advanced photon detector arrays for astrophysics from mm to X-ray wavelengths

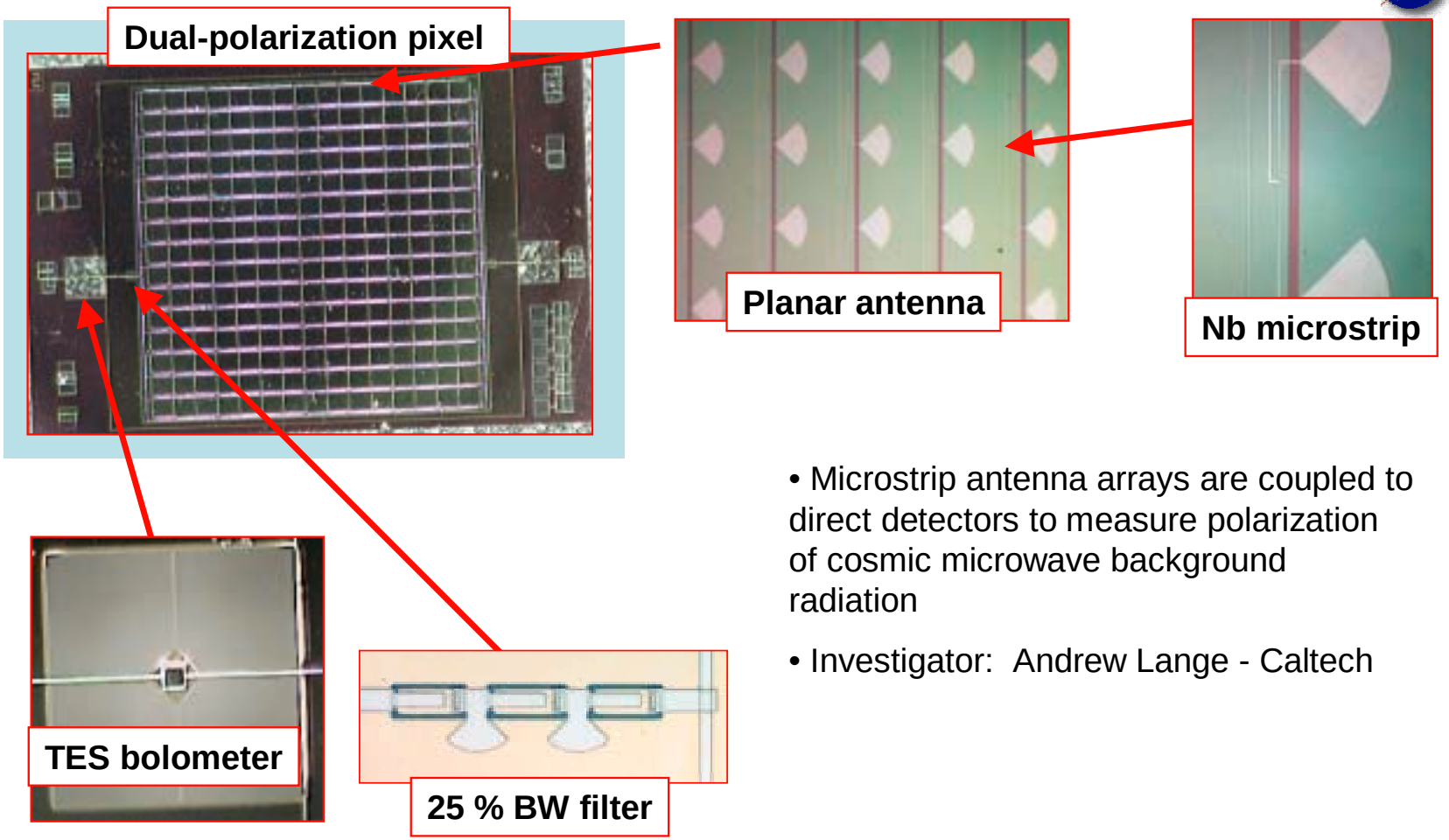
- New concept: microwave readout of quasiparticles
  - Quasiparticles change kinetic inductance (surface reactance) of superconductor
  - Kinetic inductance influences resonant frequency of thin film microwave circuit
  - Measure microwave transmission amplitude and phase

- Investigator:  Jonas Zmuidzinas - Caltech



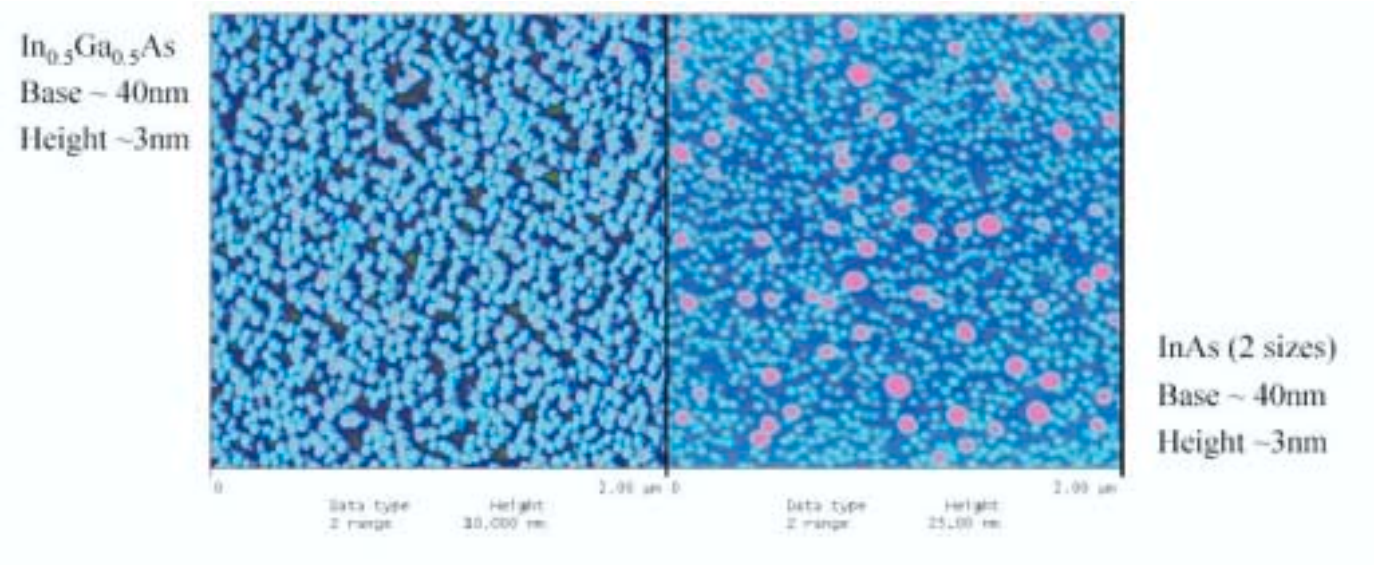



# Superconducting Antenna Coupled Multi-Frequency Bolometer Arrays




- Microstrip antenna arrays are coupled to direct detectors to measure polarization of cosmic microwave background radiation
- Investigator: Andrew Lange - Caltech

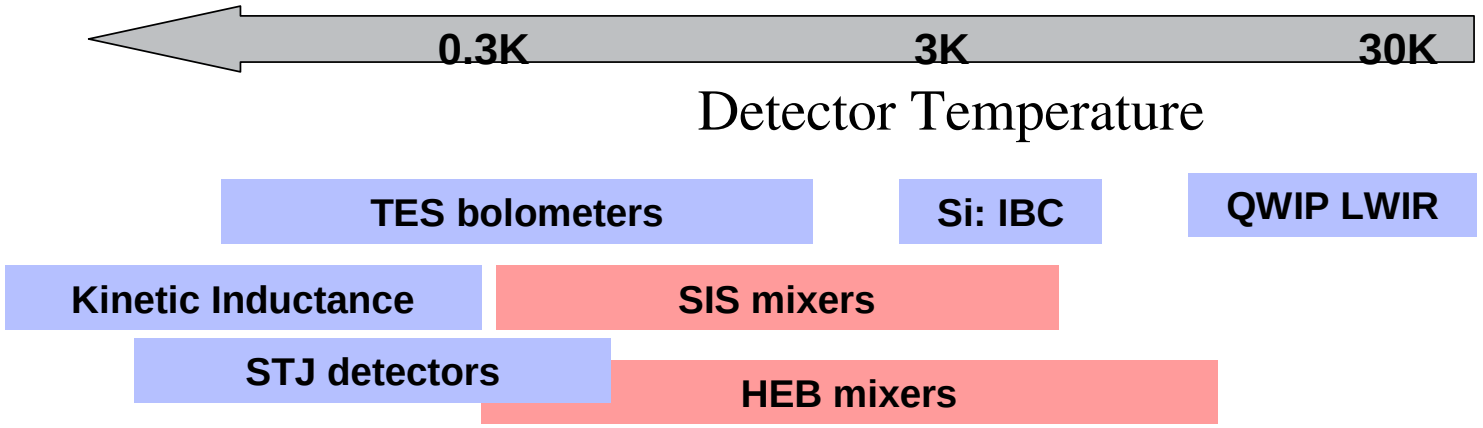
# *Quantum Dot Infrared Photodetectors (QDIPs)*




- Semiconductor quantum dots confine carriers in all 3 dimensions, creating discrete energy levels.
- QDIPs are promising higher quantum efficiency, lower dark current, higher operating temperature, and high radiation tolerance.
- InGaAs and InAs quantum dots have been grown in GaAs substrates with Molecular Beam Epitaxy
- Investigator:  Sarath Gunapala - JPL

# *Cryogenic Technology*

Improvement in Cryogenic Technology is CRITICAL to allow advancements in high performance focal planes.




**Keys for development in this area**

- Cooling power consistent with focal plane or mixer
- Vibrationless methods to reduce microphonic noise
- Ability to reject heat appropriately and interface with other stages of cooling system

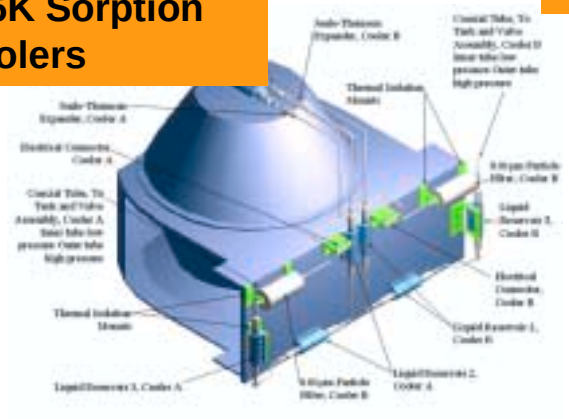
# *Cryogenic Coolers*

## 20K Pulse Tubes with Advanced Regenerators

20 K Pulse Tube (concepualization)  95 K Pulse Tube (mock-up)

## 4 - 10 Kelvin Turbo-Brayton

## 20K and 6K Sorption Coolers



## Millikelvin ADR Coolers

# MSMT-2004 NASA Research Announcement

- NASA Research Announcements (NRAs) are broadly-competed peer-reviewed solicitations for exploratory research and technology development activities.

- Code R will issue a $39M NRA for Mission and Science Measurement Technologies (MSMT-2004) on August 4. The NRA will include three main technology areas:
  - Advanced Measurement & Detection (includes focal planes and cryocoolers)
  - Large Apertures
  - Low Power Electronics

- Draft NRA will be posted on the web June 23 for public comment at: http://research.hq.nasa.gov/

- Bidders Conference will be held at University of Maryland Conference Center on July 15.

- NRA is open to all categories of organizations, including industry, universities, non-profit institutions, NASA Centers, and other government agencies.

- Typical funding awards are $300K - $500K per year for 3 years.